Comment on "Self-Heating versus Quantum Creep in Bulk Superconductors"

In a recent Letter [1] Gerber and Franse report power dissipation and magnetic relaxation measurements on a BiSrCaCuO superconductor monocrystal down to 0.5 K. They state that the observed power dissipation due to vortex movements combined with low thermal conductivity at low temperatures could produce a substantial temperature gradient between the center and the surface of the sample. They suggest that low temperature relaxation measurements on a wide variety of superconductors which have been interpreted in terms of quantum vortex tunneling are in fact strongly affected by self-heating.

The argument of [1] depends crucially on the calculation of the internal temperature gradient. They use the formula

$$\Delta T = P/kl$$

for the difference in temperature between the center of the sample (where the heat is assumed to be emitted) and the surface. P is the power dissipated and k the thermal conductivity. This formula refers implicitly to a sample in the form of a cube of side l. The sample used in [1] was in fact a slab $2 \times 2 \times 0.5$ mm so S the surface perpendicular to the heat path is $16l^2$ where l is the thickness. The appropriate formula for the slab cooled on one side in the limit of small ΔT is

$$\Delta T = Pl/2kS = P/32kl.$$

Using a power dissipation 1.5 nW [1] and a conductivity $k = 2500T^3$ μW/K^4 cm [2] we calculate $\Delta T = 4 \times 10^{-7}$ K at 1 K and 4×10^{-4} K at 0.1 K. For the BiSrCaCuO used in Ref. [3] the sample was much thinner and we estimate $\Delta T = 4 \times 10^{-10}$ K and 4×10^{-7} K at 1 K and 0.1 K, respectively. (0.1 K was the lowest temperature used in these experiments.) We conclude that the temperature gradient effect is entirely negligible in both these experiments and probably in all those quoted in [1].

We can note that for BiSrCaCuO and YBaCuO samples the low temperature relaxation rate plateau sets in at about 1 K [3,4] and for TlBaCaCuO at around 5 K [5]. Thermal conductivity being much higher at 5 K there seems even less reason to invoke thermal gradients.

The thermal dissipation effects could become significant in measurements on large samples at temperatures of a few mK. Thermal avalanche effects in large crystals [1] are well documented [6]; large samples should be avoided for relaxation measurements.

The results of different groups on different compounds, on samples of different sizes, and in different experimental setups give consistent data [3–5] which indicate unambiguously that in short coherence length superconductors there is an intrinsic vortex creep at low temperatures which is not thermally activated. Quantum vortex tunneling appears to provide a very plausible explanation of these experiments [7].

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